



NCAR

Current Status and Future Directions in the Use of High-Resolution Atmospheric Models for Support of T&E

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Weather Forecasting as a High Performance Computing problem

- *The world's first electronic computer (ENIAC*) was developed by “Army Ordnance” (Aberdeen Proving Ground) to compute World War II ballistic firing tables.*
- *In addition to ballistics, the ENIAC's fields of application included **weather prediction**...*

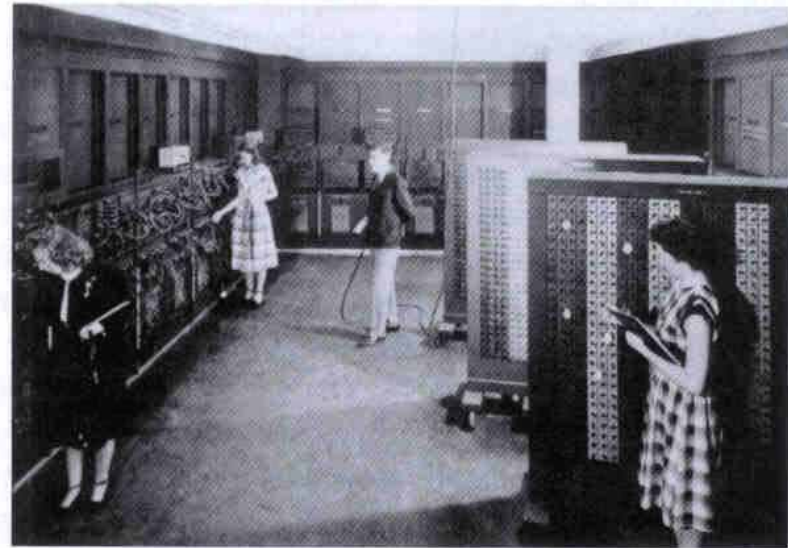


Figure 3: The ENIAC computer in 1948. The operators are changing the plug-in wiring. (PLATZMAN, 1979).

*Electronic Numerical Integrator And Computer

More recent indicators of weather's dominant role as a user of high-performance computing

- 1952 - Princeton's Institute for Advanced Study developed first general-purpose computer; the primary intended use was weather prediction and research
- 1977 - The National Center for Atmospheric Research was Cray Research's first official customer with the Cray 1A
- 2000 – Europe's three fastest super computers were dedicated to weather forecasting
- 2005 – 10-20 of the top-100 super computers in the world are utilized primarily for operational weather forecasting or weather research

Why Numerical Weather Prediction is Computationally Intensive

- Nonlinear, nonhomogeneous, partial differential equations that describe fluid dynamics and thermodynamics of the atmosphere must be solved with high-order numerical techniques
- Physics of atmospheric turbulence, radiation, chemistry and cloud/precipitation processes are complex
- Soil, vegetation, ocean processes are part of model
- Because of the numerics, a doubling of the resolution in horizontal and vertical requires a 16-fold increase in the computing power required for the same area

History of ATEC Four-Dimensional Weather (4DWX) Program

- Situation in 1995 – Unmet needs of Army test range forecasters
 - range-scale model products,
 - a modern data archival system, and
 - better graphical displays of data and model products
- 1996-present – ATEC and the National Center for Atmospheric Research have partnered on the development of one of the highest-resolution operational weather-prediction systems in the world

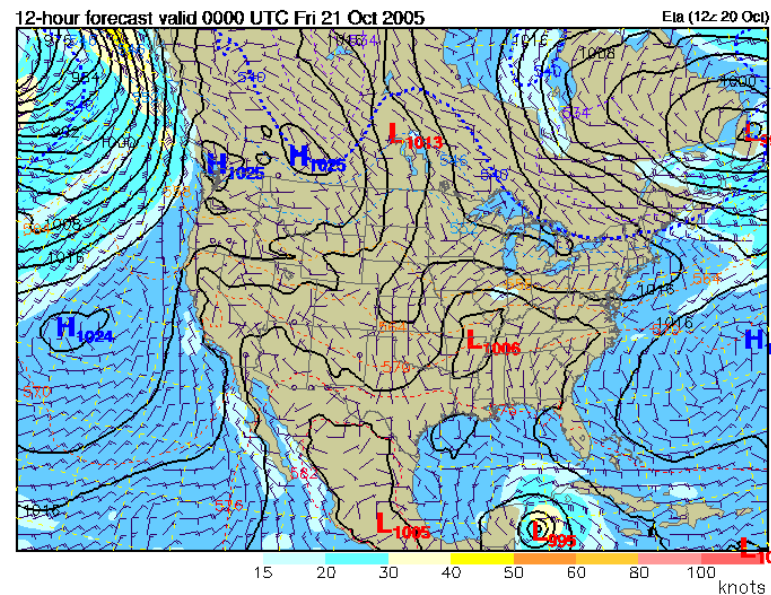
Paradigms of the ATEC 4DWX Program

- Partnership and close collaboration between ATEC meteorologists and system developers
- Rapid prototyping and deployment of new capabilities – concept to operations in 3-6 months
- Frequent upgrades/releases – system is NOT static

An example – Standard versus 4DWX model forecasts

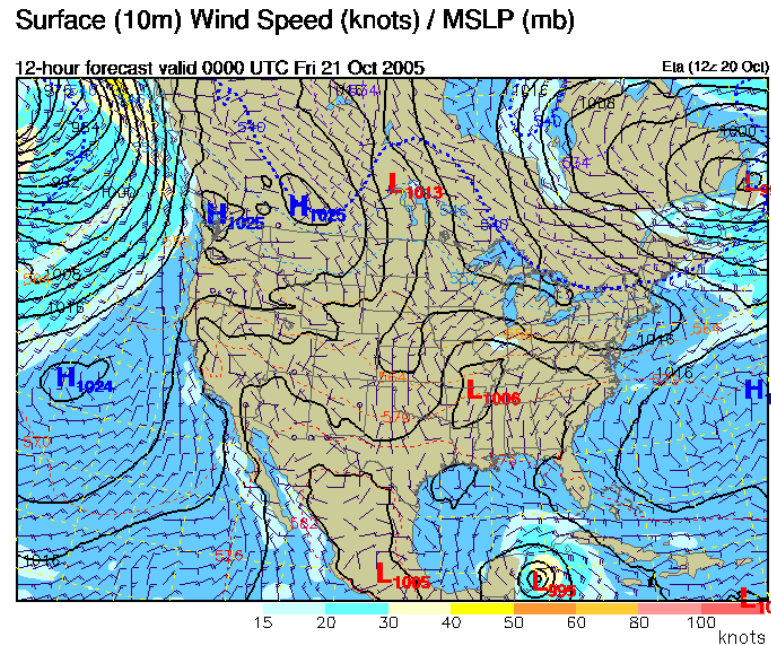
Standard model forecast from
National Weather Service

Surface (10m) Wind Speed (knots) / MSLP (mb)

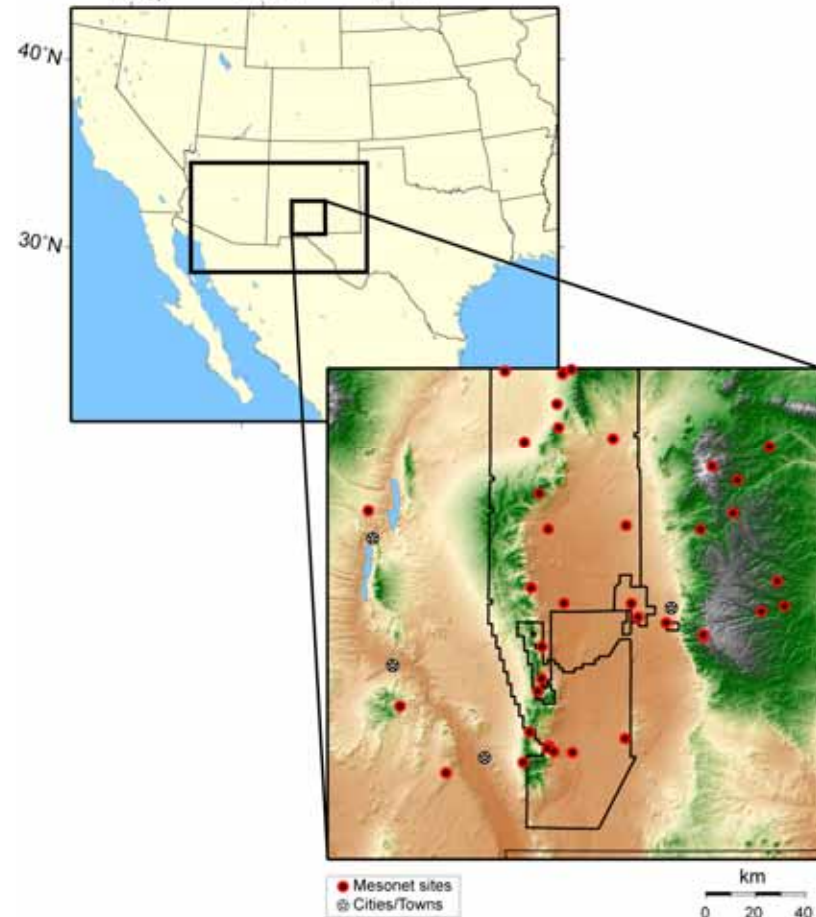


For example - model forecasts

Standard model forecast from
National Weather Service



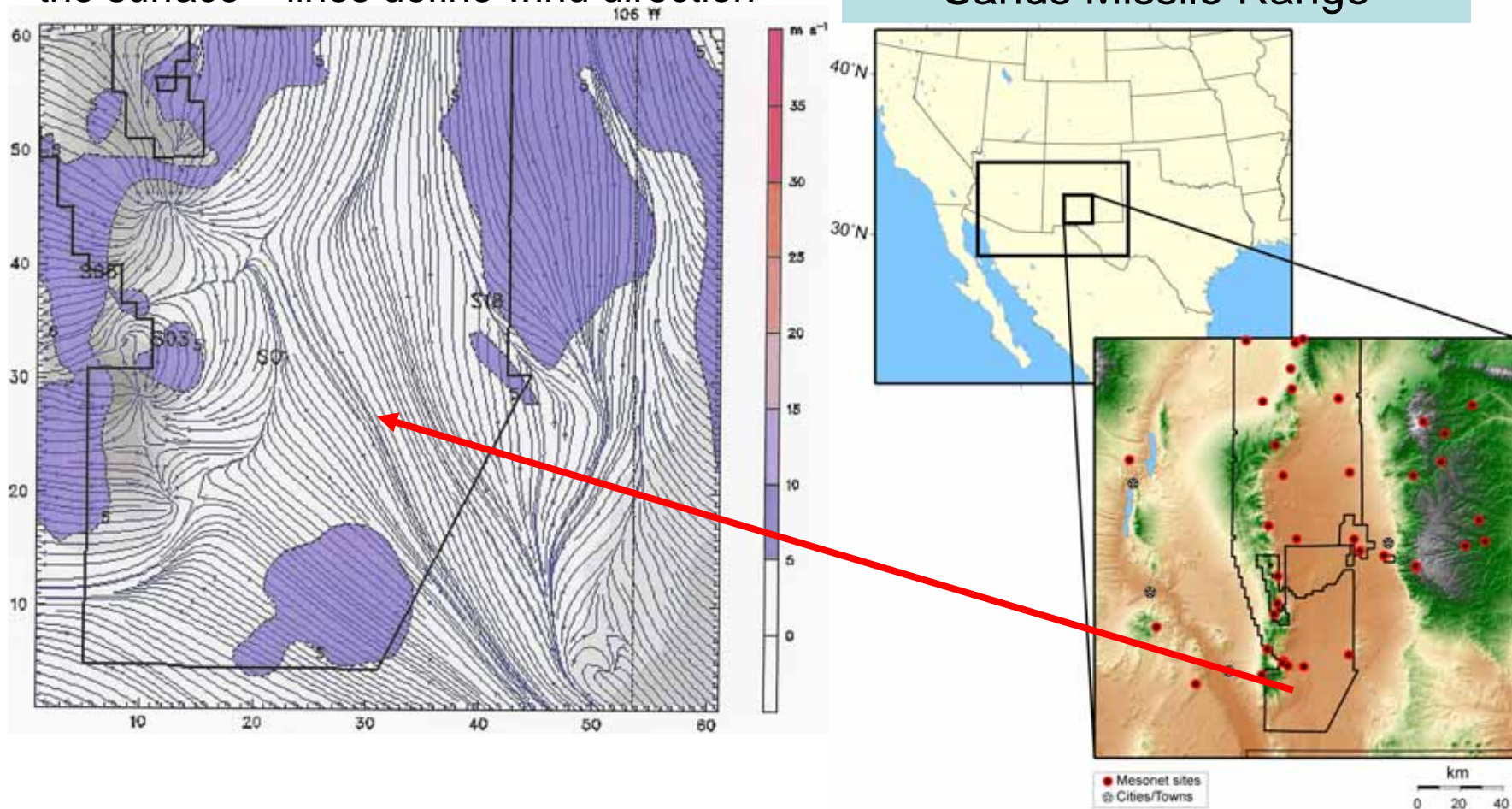
Current 4DWX model
computational area for White
Sands Missile Range



For example - model forecasts

Complex forecast wind-flow pattern near the surface – lines define wind direction

Current 4DWX model computational area for White Sands Missile Range



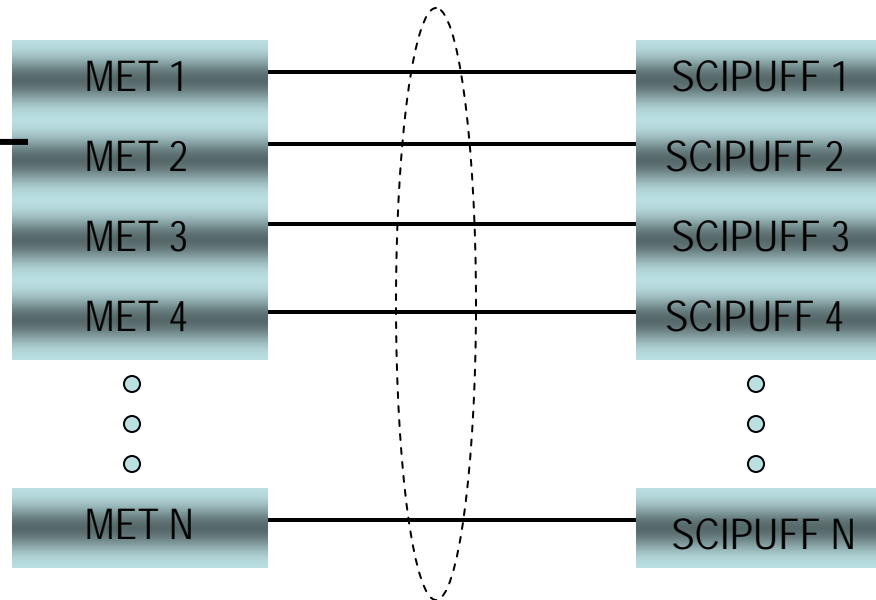
Why haven't standard products been able to serve ATEC's weather needs?

- Test ranges have specialized weather needs – e.g., boundary layer winds
- Models need to be especially high resolution because of nearby complex topographic and coastal forcing
- Weather models need to be closely coupled to special-applications models – transport and diffusion, parachute drift, sound propagation

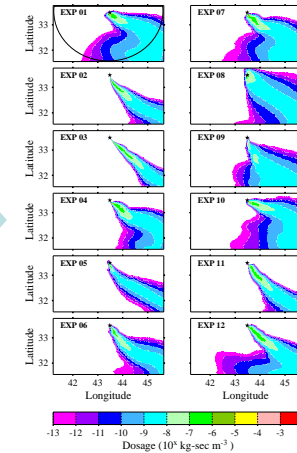
New High-Performance Computing Requirements for ATEC 4DWX System -- EXISTING EFFORTS --

- **Ensemble prediction** – multiple parallel model runs provide probabilistic forecasts to T&E customers
- **4DWX On The MOVE** – graphical interface to weather model allows support of world-wide operational and virtual testing by non-experts
- **Global Climatological Analysis Tool** – constructs high-resolution analyses of regional climate for long-range test planning, at ranges or worldwide
- **FCS/VPD Support** – 4DWX model provides very-high-resolution atmospheric environment for virtual testing

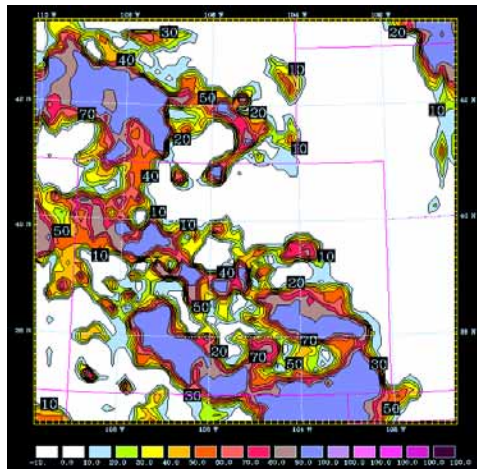
ATEC Ensemble Prediction



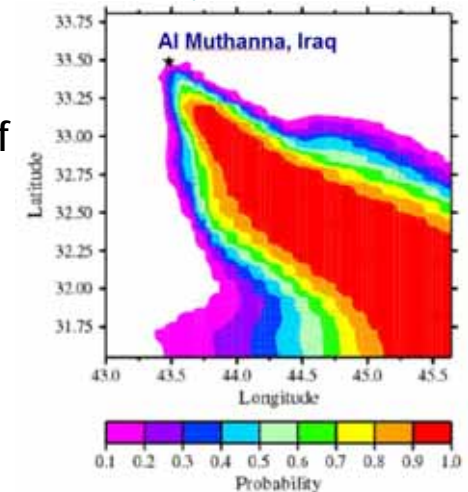
Plume ensemble output



Met. ensemble
output:
probability of
winds > 5 m/s over
Colorado



Probability of
dosage
exceedance



ATEC 4DWX On The Move

- Graphical interface is used to deploy operational weather modeling system
- Used to support special missions that are not covered by stationary range weather-modeling systems
- Example – WSMR support of missile launches in Hawaii

The Graphical Interface:

for quickly configuring and running
the 4DWX forecast system

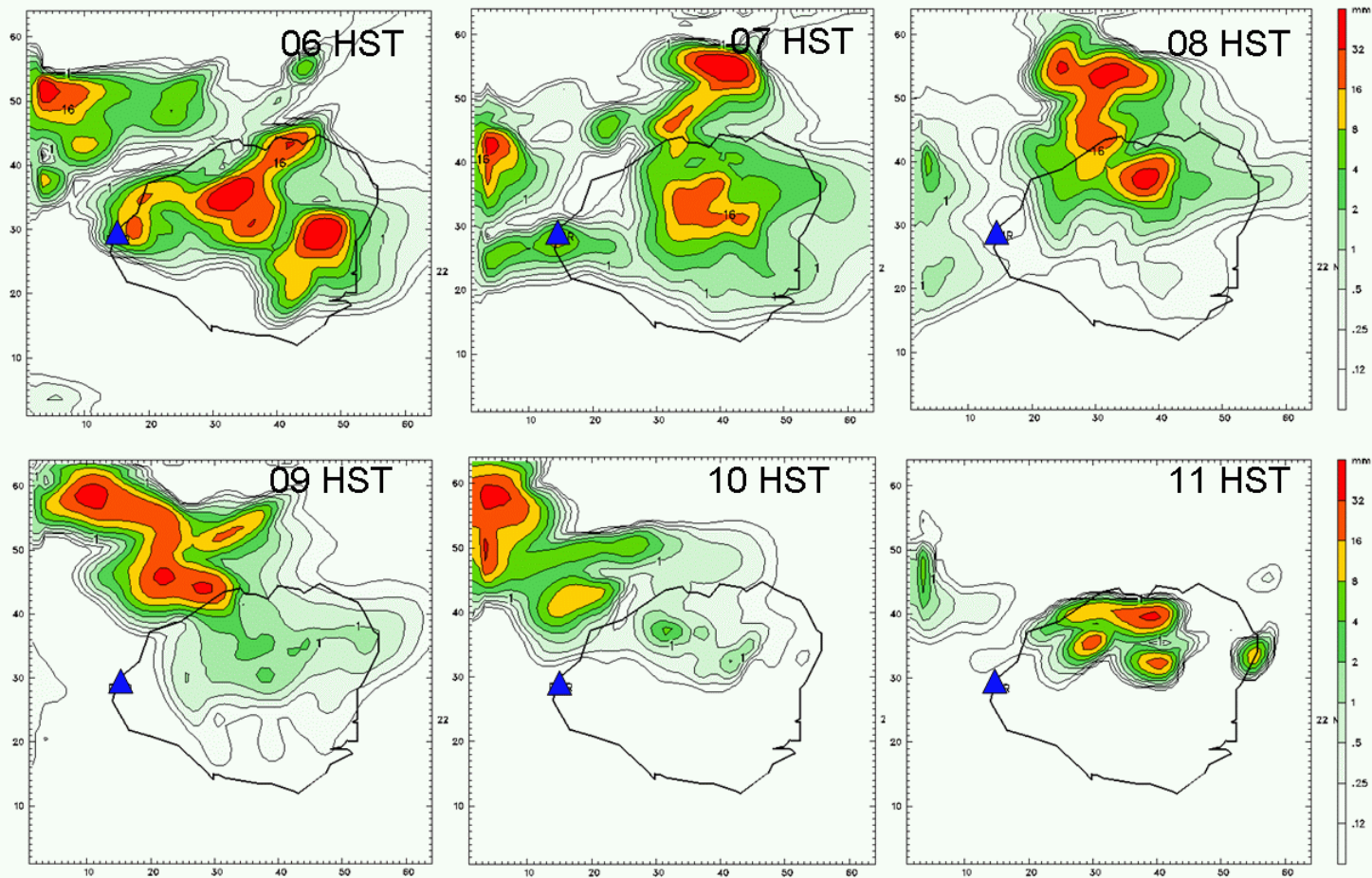
The screenshot displays the graphical interface for the 4DWX forecast system, specifically the 'Location Setup' page. The interface is organized into several sections:

- Navigation Bar:** Includes links for Home, Job Manager, New Job, Search Job, and My Jobs.
- Welcome Message:** Greeting the user 'ngicuser' and providing a 'Log Off' option.
- How to configure:** A sidebar with steps for configuration: Step 1: Config Setup (ClimoFDDA18), Step 2: Location Setup (current), Step 3: MMS Config Setup, and Step 4: Timeline Setup. It also shows the current state as 'PRECONFIGURED' and options to 'Start over' or 'Discard job'.
- Location Setup Page:**
 - Map Tools:** A list of navigation tools including 'Update map', 'Return to Full Extents', 'Zoom Factor', 'Zoom In More', 'Zoom Out More', 'Recenter the Map', and 'Save map'. There is also a checkbox for 'Draw domain on map'.
 - Map:** A central map showing the Hawaiian Islands. The map is labeled 'HAWAII' and 'UNITED STATES'. Below the map, the coordinates are displayed: Latitude: 22.293 N, Longitude: 159.626 W.
 - Key Map:** A small inset map showing the location of the main map area within the context of the world.
 - Map Services:** A section for selecting map layers, including 'Base Map Layers', 'World Satellite Imagery' (checked), 'World Base Map', and 'Country Boundaries'.
 - Map Utilities:** A section for zooming to boundaries, showing coordinates for NW (22.307, -159.79), SE (21.79, -159.20), and an 'Update' button.
 - Domain size and centroid:** A section showing the domain size as '100x100km' and the domain centroid coordinates as Latitude: 22.040, Longitude: -159.499. It includes a 'Zoom Domain' button.
- Footer:** A button labeled 'Add to configuration'.

The situation in the early morning of 2 Feb 2005

- Mission: Rocket launch scheduled for 0800-1100 HST.
- Weather conditions at 0200 HST:
 - Persistent moist unstable flow over Kauai causing widespread thunderstorms.
 - Most of Kauai under a Flash Flood Warning.
- Situation looked highly unfavorable for a launch, but model was predicting a break in the rain between 0900 and 1100 HST.

The ATEC-model forecast from the previous evening:
Heavy rain until about 0830 HST, followed by rapid clearing



(PMRF station is marked as blue triangles)

Case of Feb. 2 2005

Later that Morning (02 Feb 2005)

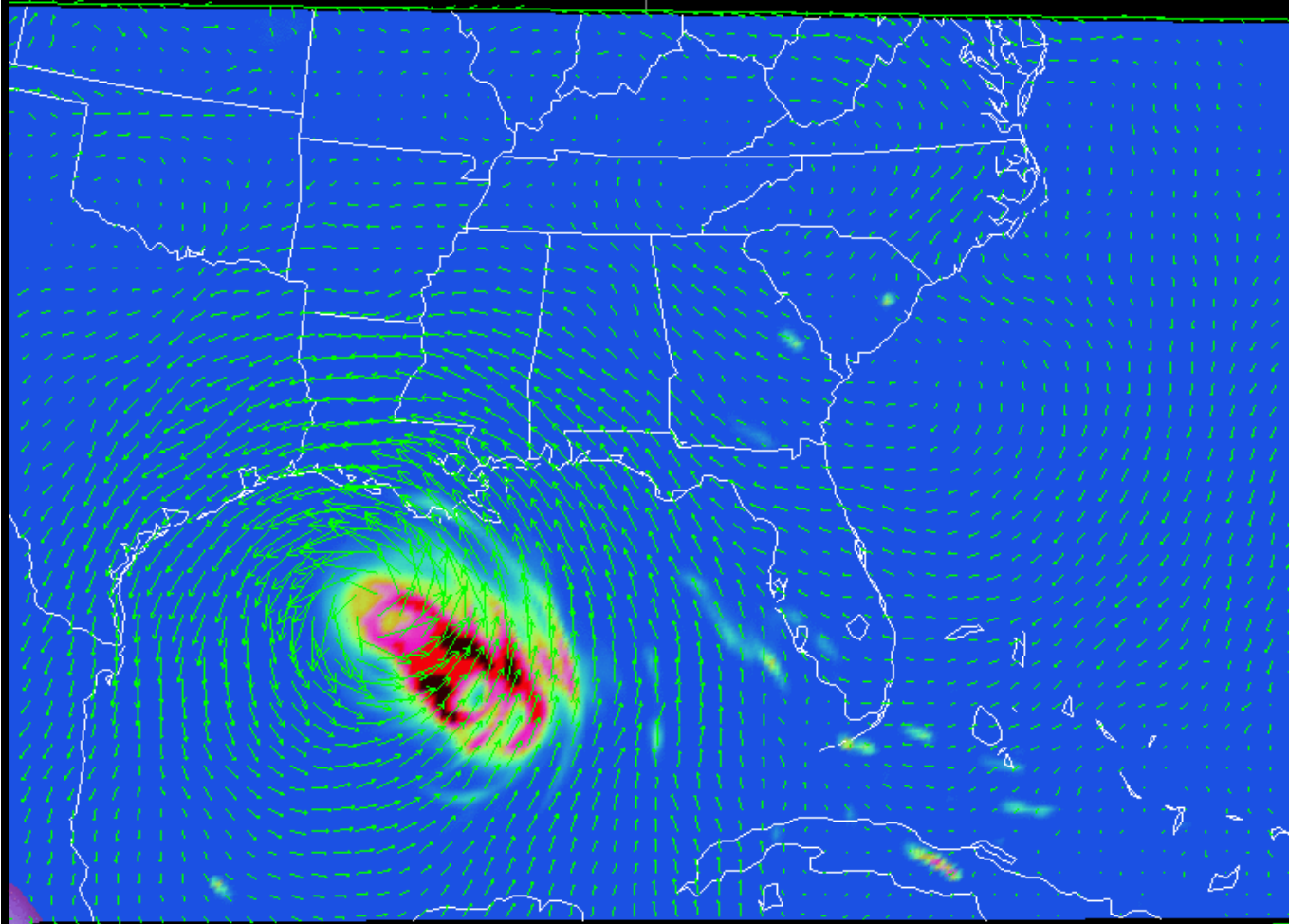
- 0600 HST: Little improvement in observed weather conditions.
- 0830 HST: National Weather Service radar indicated a break in the thunderstorm activity.
- 0900 HST: Rain ends and skies clear, as forecast by the model.
- **Rocket successfully launched.**

ATEC 4DWX On The Move – A National Asset

Supporting the Department of Homeland Security's
forecast of the impact of Hurricane Rita on
the National infrastructure

14:00:00
23 Sep 2005
1 of 57
Friday

N



Colors –
storm total
precipitation

Surface winds and accumulated rain (Magenta: > 150 mm; red: > 250 mm;; black > 350 mm)

Vis5D

Global Climatological Analysis Tool

- Model is run for decades-long historical period to “downscale” available global climatological analyses
- The resulting high-resolution climatology of winds, temperature, etc. can be used for long range test planning
- The system can be used for range T&E or operational testing worldwide
- National Ground Intelligence Center now uses this system operationally; it will soon be deployed to ATEC ranges.

Example Of Application of Global Climatological Analysis Tool

What is the typical pattern of atmospheric transport of hazardous material over the Korean Peninsula in March?

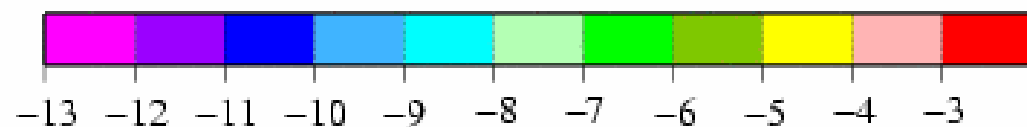
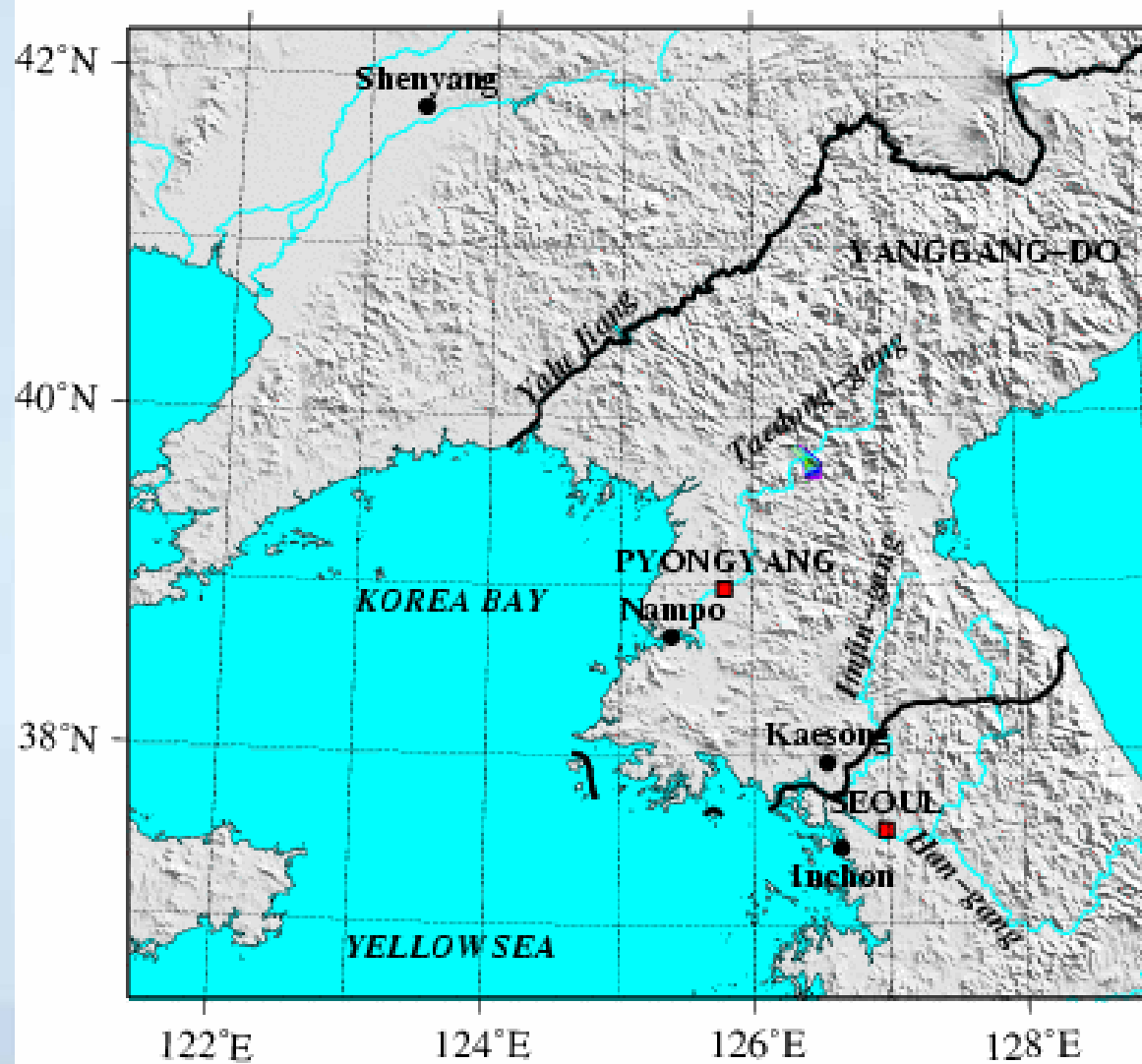
GB

03/15/1987 13:00 GMT



NCAR

Day 1



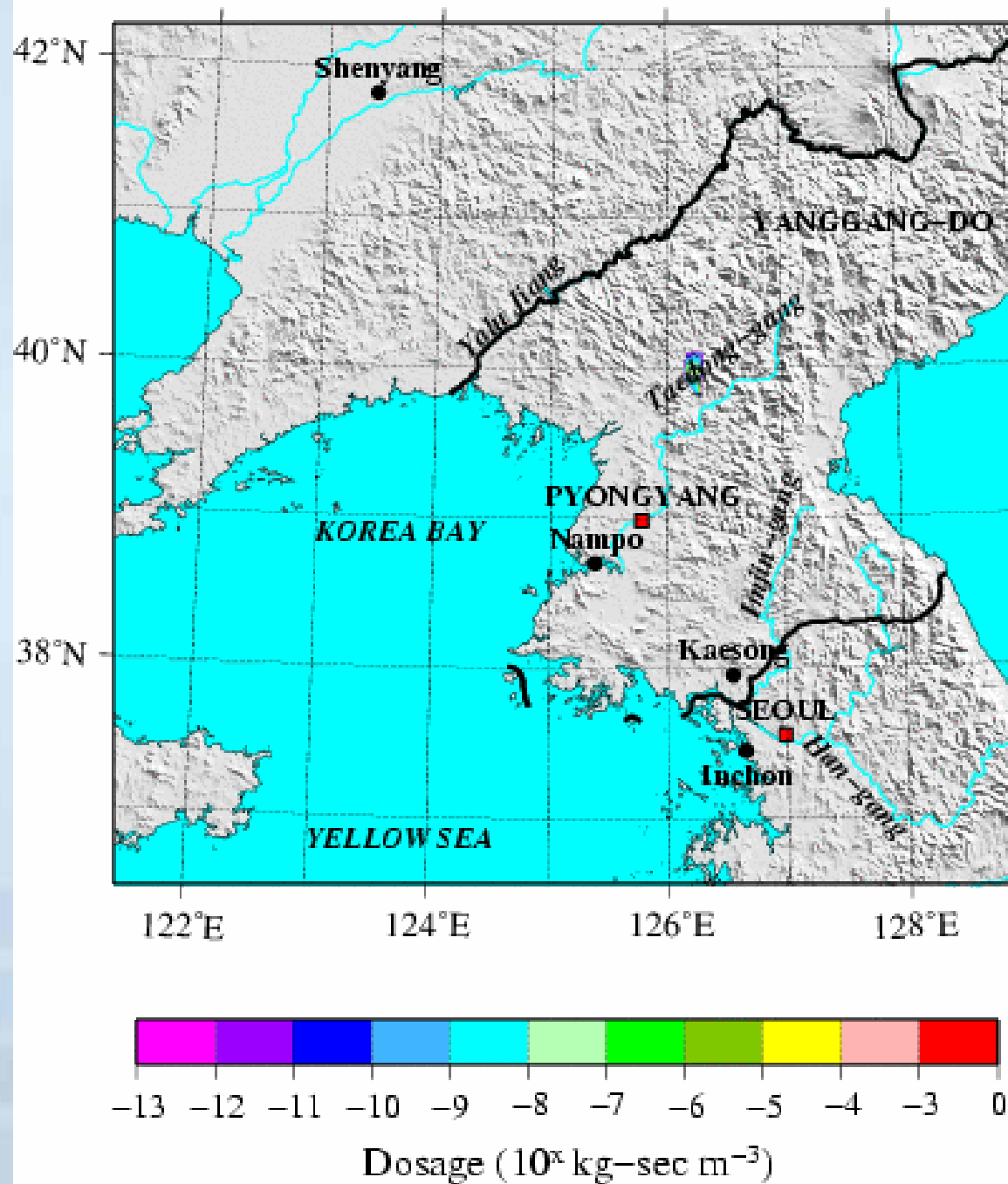
Dosage ($10^x \text{ kg-sec m}^{-3}$)

GB 03/15/2004 13:00 GMT

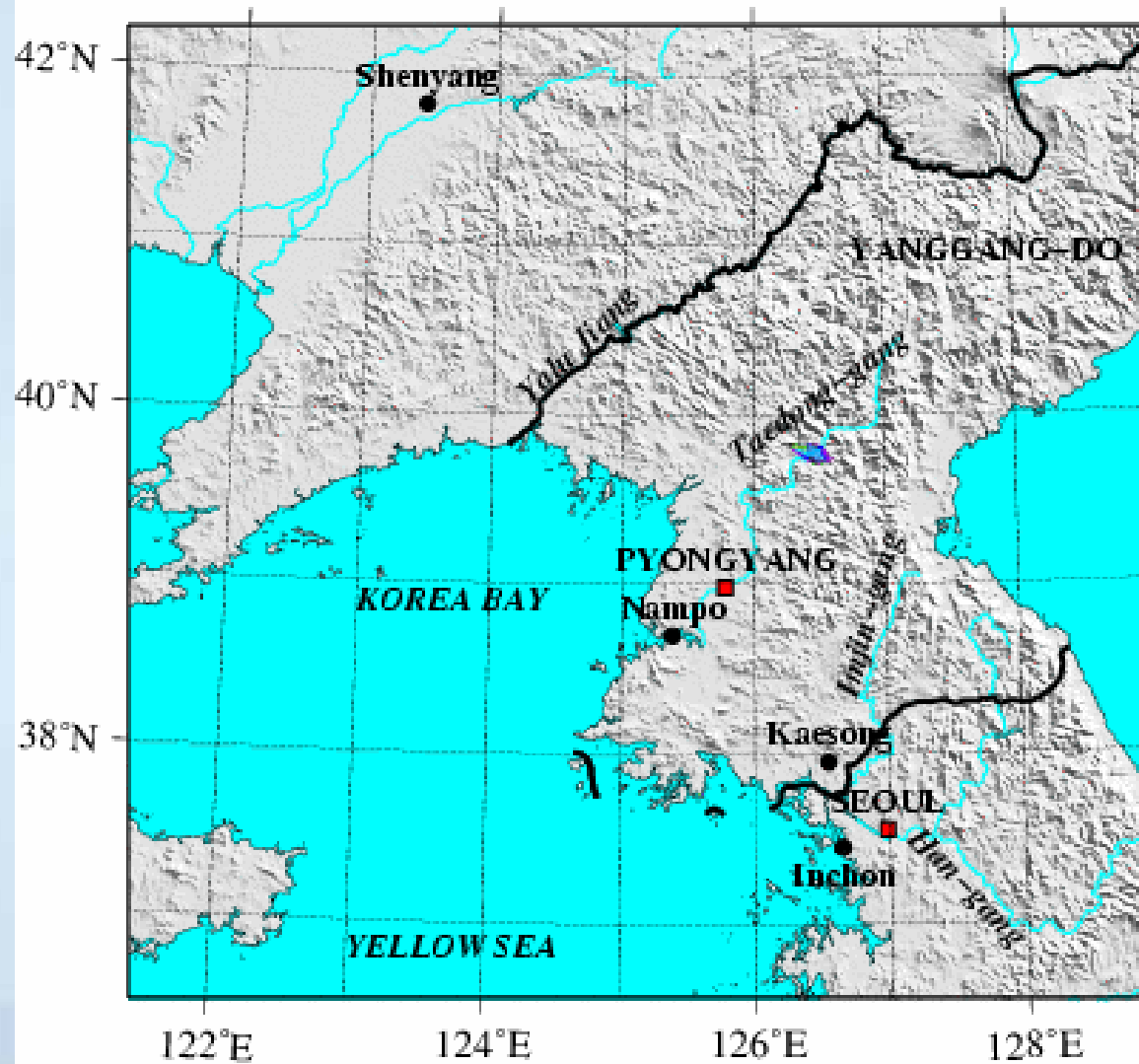


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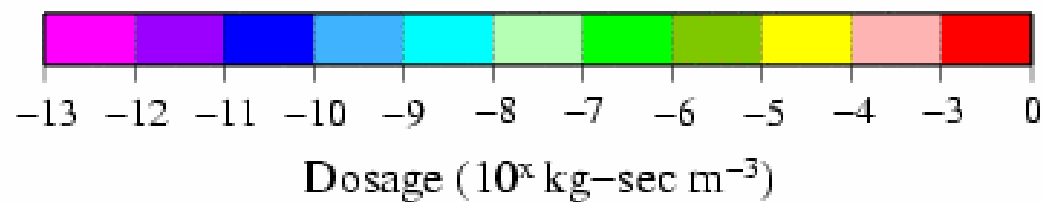
Day 2



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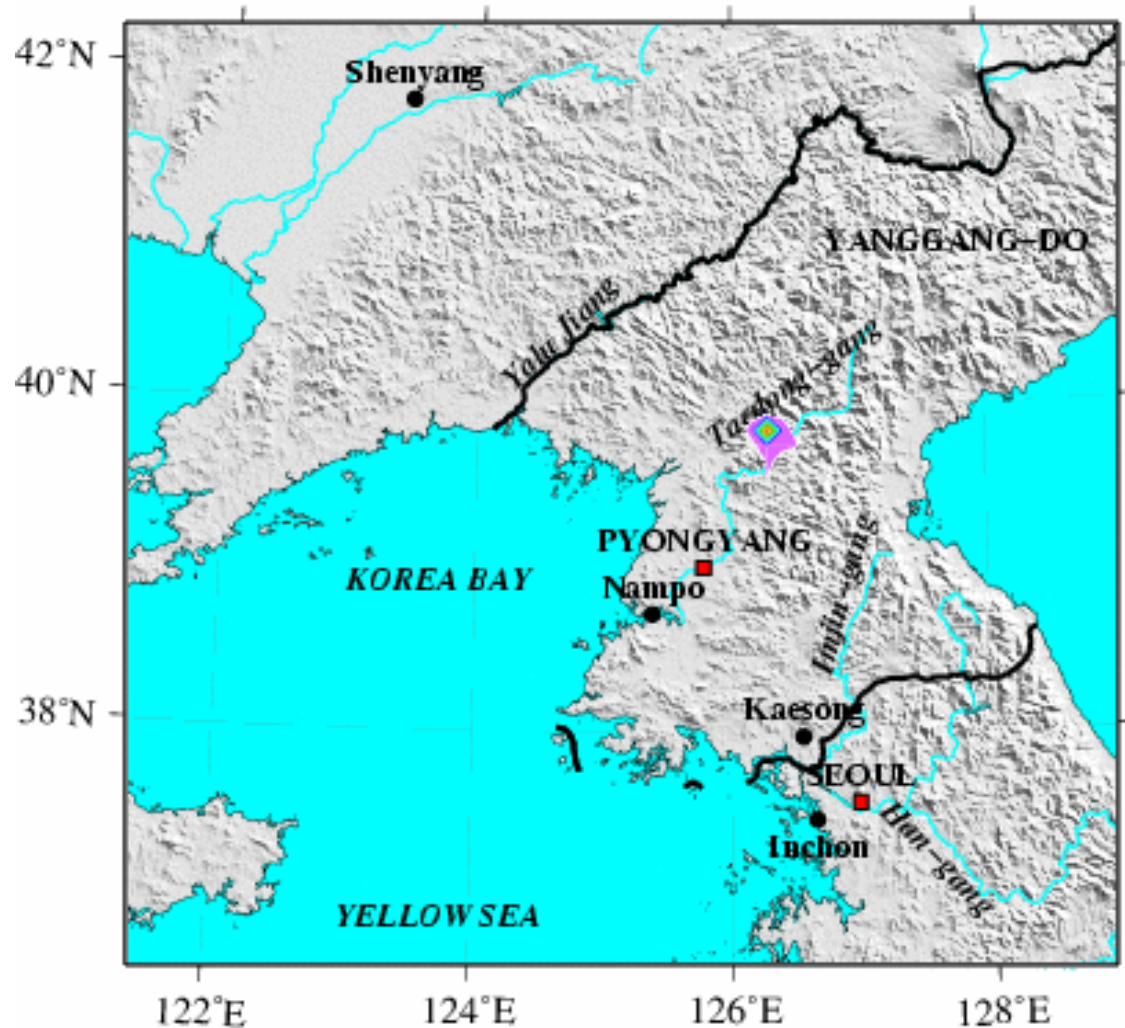


Day 3
etc.



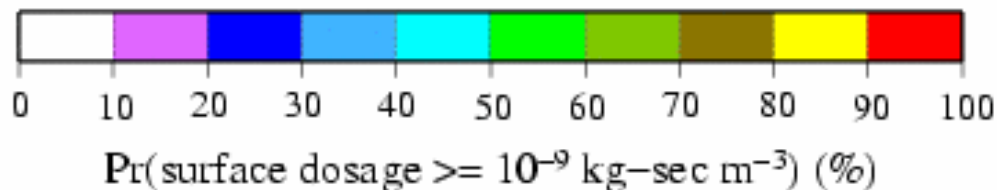
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Probability of
Exceeding a
Dosage
Threshold

Based on an
ensemble from
large number of
case days in
March

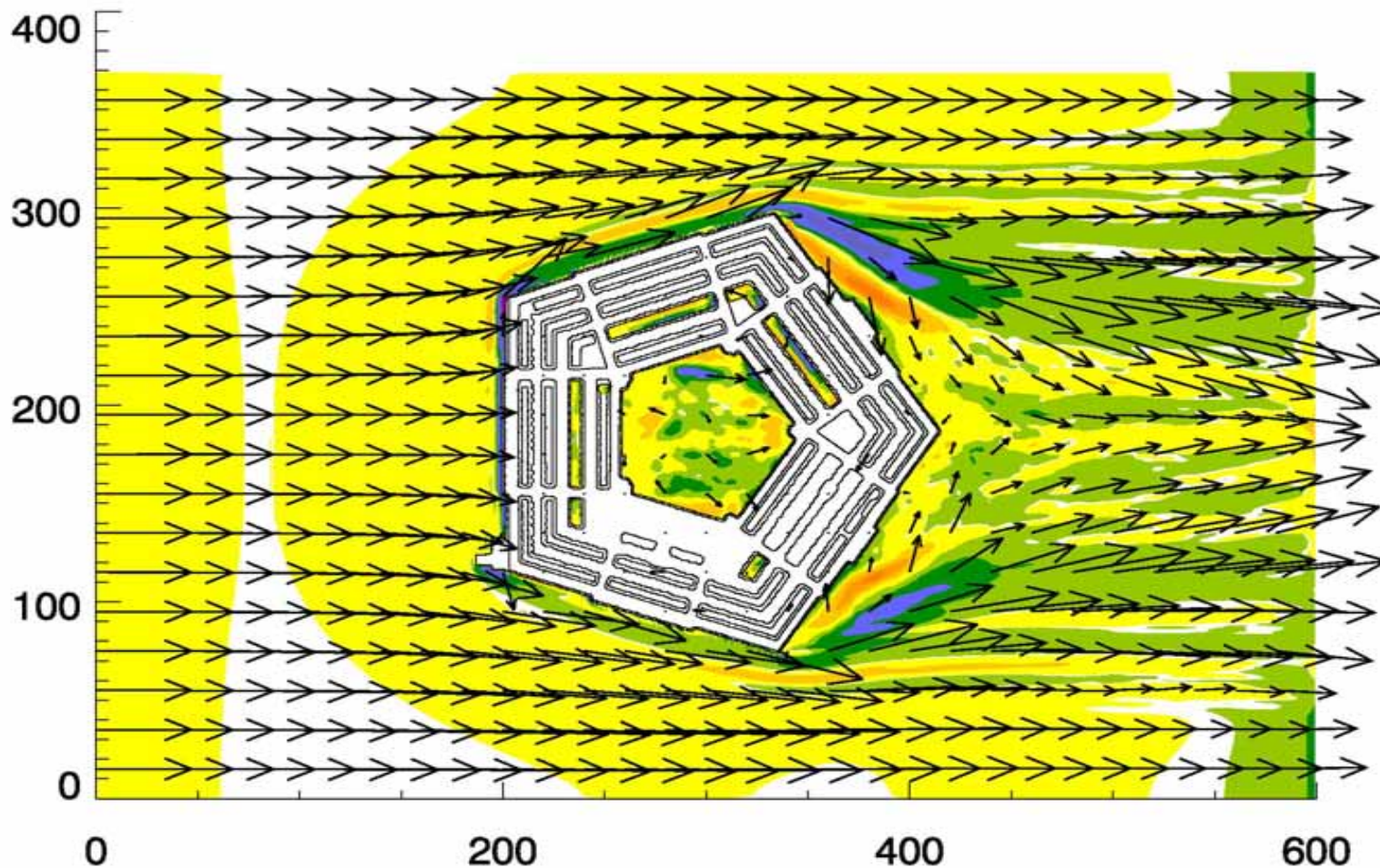


A New Extremely Computationally Intensive Direction for T&E Modeling

- Building-aware computational fluid dynamics models
- Application – Actual and virtual testing in urban settings
- Computationally intensive because grid increments must be about 2 meters to resolve building and street-canyon effects

Example – Modeled wind flow around the Pentagon

W z = 5 neutral mean



Summary of New Computationally Intensive Atmospheric Modeling in Support of T&E

- Ensemble prediction is providing probabilistic information to customers
- High-resolution atmospheric forecast systems can be deployed worldwide for operational testing
- Model-based very-high-resolution climatologies can be generated worldwide for long-range test planning
- FCS/VPD is beneficiary of high-resolution modeling and climatological-analysis capability
- ATEC 4DWX model is being coupled to building-aware urban models